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THE REHABILITATION OF THE AMERICAN COLLEGE, AND THE PLACE OF CHEMISTRY IN IT[1]

THERE are two subjects which at present occupy the focus of public interest in the United States; namely, the American tariff and the American college. One difference between the situations in the two cases seems to be that whereas a few people are strongly in favor of the tariff, nobody has a good word to say for the college. Perhaps a reservation should be made in regard to the latter; one senator, apparently, thinks that the negative quality of inefficiency is better than none at all. His words are: "I love my *alma mater* for all she has enabled me to be and to do, in spite of herself." He finds virtue in her very laxness.

Can we as chemists confidently feel that Flexner and Birdseye in their voluminous writings, and the myriad commencement orators in their more or less seasonable outpourings, have all spoken with a definite mental reservation? Can it be that all the unpleasant things that they have said were intended to apply to the whole structure of the American college, with the sole exception of its department of chemistry? I fear not. If then the American college is an Augean stable, shall we wait in the hope that some Hercules will come and clean it all in twenty-four hours, or shall we take off our coats and tackle the problem of our own stall?

[1] An address before the Section of Education of the American Chemical Society, at the Detroit meeting, July, 1909.

THE OLD COLLEGE AND THE NEW

The early American colleges suffered from no such torrent of criticism. For a time, indeed, some of them were blamed because they raised money for religious instruction by means of lotteries. But against the seriousness of their scholarship and the strictness of their discipline no voice was raised. The Latin, the New Testament Greek, the Semitic languages and the essay writings, sermon making, public speaking and debating, which practically filled the curriculum, were precisely the subjects required for their purpose. They were professional schools of divinity, and seventy-five per cent. of the graduates eventually became clergymen. Even to those who became lawyers and physicians, most of these subjects did not come amiss. The law was written in Latin and briefs and writs were prepared in Latin. Even the works on medicine were printed in the same tongue. The general appropriateness of the requirements was so evident that the student could not help being held fast, and could not help being carried along by the purposeful spirit of the place. Other learned institutions did not exist, and after a little more study, and some practical experience, the graduate was ready for his duties as preacher, lawyer or doctor.

Many changes, of which two may be mentioned, have altered the whole situation. In the first place, with the development of our knowledge along medical lines, and the greater demands made upon the lawyer and the clergyman, the college can no longer affect to be in any sense a professional school. It furnishes as much training in the same subjects as ever, in fact it furnishes more, but all that it does is so much smaller a fraction of the total professional course, that the purposeful state of mind of the professional student has entirely left its walls.

In the second place, the influx of another body of students will soon have reduced to a minority the proportion of its graduates destined to enter one of the learned professions. Only three or four per cent. of the graduates of Yale (formerly the official divinity school of the neighboring colonies) now enter the church, while forty per cent. become business men. Yet the American college has never attempted to be a professional school of business. Thus, by its failure to retain its old character as a professional school, the college has lost one of the main sources of its hold upon the interests of the student body. The colleges could not follow the development of all the professions, so they made no attempt to follow any. With the help of the elective system, they became bargain counters, or rather, since there was not always even a salesman specially deputed to give advice, the more advanced ones became mere automatic cafés.

Simultaneously with all this, the college has given up its attempt to form the character of its students by the enforcement of strict regulations. The student is no longer guarded against all temptation to form bad habits. He is no longer furnished with exercises and customs calculated to produce good habits.

Thus the college has relinquished its once effective plans for training professional men and for turning out men of character. The structures which performed these functions have fallen into disuse. The college as an educational institution is biologically a mere rudiment of a formerly vital and useful organ in the body politic. As one of its critics has said, "It is a sort of educational vermiform appendix."

Given an appendix, appendicitis is sooner or later bound to appear. We are now at

the bedside of the patient and, judging from the statements of numerous experts, the college appears to be the seat of a most violent inflammation. What is to be done with the victim of this appalling disease?

Analogy suggests that the offending organ might be cut off. But the American college, not being attached to anything, can not be removed. We might resolve to abolish the American college, but the American colleges would remain. And perhaps, after all, there is a place for the American college. The professional schools are rapidly adding a certain amount of college work to their admission requirements. It is true that some high schools have added two years to their curriculum, but the gap between the high school and the professional school is widening faster than it can be filled by the development of the secondary institutions. Here is still ample room for the American college.

THE COLLEGE A PLACE FOR CULTURE

We must regard as purely futile the suggestion that the college should be turned into a place for culture, if by this term is to be understood something distinct from scholarship. Flexner[2] quotes with approval the statement of Professor Mann, in which, after indicating the rigid nature of the work of technical students, he says:

> For the non-technical or general student, college laboratory work is neither essential nor desirable; the emphasis in this case should be laid upon the services of science in developing and maintaining intellectual, social and economic life.

An education composed entirely of this sort of work will not appeal strongly to chemists. Are not deep knowledge and rigid training in science required before the services of science in developing intellectual, social and economic life, can be properly appreciated? Is the giving of a culture course of this description not an attempt to produce *fruit* without the assistance of organs of nutrition and growth? Is a course which sets out with the definite aim of conferring culture, and nothing else, ever anything but a "soft snap"? Stimulating it may be, if given by an exceptional personality, but a good deal like the lemon phosphate and the ice cream soda, temporary in its effects. It pleases our palate for the moment and a week later is not even so much as a pleasing memory. I wonder if culture is not rather to be sought as a *by-product*—a by-product of cultured parentage and sound education—rather than as an end in itself?

[2] SCIENCE, N. S., XXIX., p. 366.

THE COLLEGE FOR TEACHING PROBLEM-SOLVING

What important ends of subsequent life can the college course appropriately serve? Is not the chief exercise in every profession, and in all lines of business, that of solving problems?[3] Shall we not then so devise our methods of instruction that the student may gain experience in the exercise of this most important function. Shall we not teach him to suspend his judgment, instead of acting upon the first idea that comes into his head? Shall we not train him to search for facts, and to realize when essential facts are still lacking? Shall we not exercise him in correct reasoning from the facts when they have been secured? Shall we not, finally, show him the necessity for testing his conclusions by careful comparison with the facts and show him how to do this? This is no light program. Certainly no subject has gained a right to admission to the college course until it has demonstrated its capacity for being taught in this fashion.

[3] See Professor A. A. Noyes's recent address, "A Talk on Teaching."

THE COLLEGE AS A PRE-PROFESSIONAL SCHOOL

So much for the general aim of the instruction. As regards the curriculum, would it not be well to hark back to the plan of the old college, with suitable modifications? The college can no longer furnish complete professional training, but it can do pre-professional work. It can do work of professional quality, so far as it goes. Let us exclude from the college rigidity all those whose aims are so indefinite that they are not willing to prepare for some profession. And I include banking, insurance and other lines of business amongst the professions, for, in spite of isolated opinions to the contrary, the college *can* furnish training in the sciences fundamental to business. Let the work be scholarly, exact and thorough. Let the chemistry and physics be a suitable foundation for further work in the same subjects, or for application in physiology and other more distinctly professional studies. Let the political economy prepare for more strictly professional courses in finance and transportation. If every student is engaged in one of these pre-professional curricula, shall we not be able in a large measure to restore the purposefulness of the old colleges? True, we can never reintroduce the regulations and restrictions which guided the life and moulded the character of the early undergraduate. But, if we require every student in college to select some one curriculum, and exact of him scholarly work in every study, shall we not so occupy his attention, that waste of time will be reduced to a minimum, and social occupations will be relegated to the subordinate position which alone they are entitled to occupy?

To avoid possible misunderstanding, let me add that by pre-professional curricula I do not mean narrowly specialistic curricula. With six or eight years available for the total pre-professional and professional training, there should be ample room for breadth as well as for intensity. What I mean is that the present more or less complete waste of the first part of the total course, which is so liable at present to occur, should be rendered impossible.

TWO CHANGES IN THE PRESENT SITUATION REQUIRED

If the American college is to be rehabilitated along these lines, namely, those of teaching problem-solving and giving work of professional standard, or along any similar lines, two important improvements in the present situation are required. To give in all subjects the kind of instruction indicated will require *skilful teachers,* and it is generally admitted that the teaching of undergraduates is at present less satisfactory than is that of the pupils in the grades and high school on the one hand, or of the students in the graduate on the other. The second need is that of *more efficient methods of teaching,* particularly in non-linguistic subjects.

TRAINING IN THE ART OF TEACHING NEEDED

The various causes of poor instruction in our college classes have been discussed at length by Flexner and Birdseye. I wish to speak of only one out of the whole number. When we desire the services of a physician we seek a man who has been trained in the practise of medicine. And when we employ a lawyer we entrust our business to one who has had training in the practise of law, and not to one who has a merely theoretical knowledge of the subject. Yet when we set out to find a college teacher, we enquire for a doctor of philosophy. The doctor of philosophy is a person who has devoted several years mainly to the study of one subject and often of a small corner of one subject. He is a per-

son who has had his attention for a time directed, with the utmost insistence, exclusively to the making of some addition to human knowledge. He may be an investigator, but he is not necessarily anything else. Training in the art of teaching is not even a minor requirement for the degree. We are constantly told that teachers are born, not made. So, however, are the most successful lawyers and doctors. This "nascent" theory of teaching will not bear a moment's scrutiny. What natural mechanism exists that shall direct the born teachers into teaching, and shall prevent the born policeman and born stock speculators from drifting into the same line of work? Then again, is the born teacher necessarily able to teach without training? The discoverer of an important surgical operation was probably a born surgeon, yet, unless the story is entirely apocryphal, he destroyed a whole hatful of eyes before he found out how to perform the operation successfully. Should we permit all other surgeons, including those of less native ability, to learn the art in the same way? Since the art can be, and is, taught in a more economical fashion, should we not regard the continual repetition of the original process as an unbearable atrocity? Shall we then allow even the born teachers, not to speak of those who are not of this select group, to mutilate the minds of our youth while learning their business?

No one has yet analyzed successfully the attributes of the investigator, on the one hand, and the attributes of the teacher on the other, and placed them side by side, in such a way that the extent to which they are congruent can be determined. But, that the *natural qualities* of the investigator should include all natural qualities of the teacher, and that other qualities which the investigation *acquires by training in research* should include the whole art of teaching, can not for a moment be believed. Perhaps an analogy may serve to bring out the distinction. We might train a man in the theory of music, and drill him in musical composition, so as finally, with the assistance of his natural ability, to develop a successful composer. Yet, if the requirements for the doctor of philosophy in music did not include anything more, we should be extremely foolish to infer that the graduate would be able to perform upon some musical instrument. He would be in the precise position of that classical person who did not know whether he could play the violin or not, because he never had tried. His position would be only a shade less absurd than that of the individual (commonly known as the college president) who, knowing the candidate had never been trained to play, nevertheless selected him to fill a position in the college faculty orchestra.

Of course I am aware that the president searches diligently for *teaching experience* amongst the qualifications of the candidates, and very often succeeds in detecting distinct traces of it. But teaching experience is one thing, and skill in teaching is another. The self taught analyst is a lottery, with the chances much against the gambler. He may have succeeded in teaching himself more bad habits than good ones.

It is hardly necessary for me to say that we should welcome the investigator and, other things being equal, prefer him in making a college appointment. In the college teacher, a keen interest in research and the ability to do it are indispensable. It is for some rational method of adding to the research ability, a certain amount of instruction in the art of teaching that I am pleading. Surely some method can be devised by which the prospective college teacher may get over the cruder blunders and mis-

takes of his first years of teaching, in circumstances in which less harm will be done to the student—and perhaps to the man's own reputation. If he has already taught, it should be possible to cure him of some of the worst habits he may have formed. One of our problems seems to me, therefore, to be the improving of the teaching in college classes by some system of training college teachers.

IMPROVED METHODS OF TEACHING NEEDED

If we are to give work in college up to the professional standard and in such a way that training to solve the problems of after life is to be given, we must have, not only skilful teachers, but improved methods of teaching.

The method of teaching languages, partly because of the nature of the subject, and partly as a result of long experience, has been brought to a high degree of perfection. The grammar furnishes the laws and general principles, together with all the known exceptions. The dictionary supplies the isolated facts in such a way that they can be most readily found. The text provides the subject of study in constant and definite form. The method of studying a language is extremely simple and is easily worked into the habit of thought of the pupil. He learns from experience to suspend his judgment in regard to the meaning of the author until he is in possession of the facts. He knows exactly where to look for the facts and what facts to look for. He learns to reason correctly, and the nature of the subject is such that he almost always knows when he has reached the correct conclusion. In other words, every conclusion is tested, and every element in problem-solving by the scientific method is covered. Mistakes, when he makes them, are sooner or later detected and rectified. The method is simple, yet of unquestionable efficiency.

A method so simple and certain has not yet been devised for history, literature, political economy or chemistry. Perhaps the successful study of these subjects can never be made so easy as in the case of languages. Yet it should, at least, be possible to detect the fundamental characteristics which make the study of language successful and adapt them to the teaching of other subjects.

THE LECTURE METHOD

Can it be said that any such successful method is used in chemistry? Is there, indeed, a general method of any description in use? Most commonly a course of lectures occupies a prominent place in the scheme of instruction, and an even more prominent place in the estimation of the student. The lecture method has its advantages. The facts can be presented more graphically than by any book. The relations of the facts can be explained with greater lucidity and in a more impressive manner. Illustrations can be multiplied, as they could hardly be multiplied in a book. Experimental illustrations, which are impossible in print, can be given. Yet who would feel that a lecture on twenty-five French words, no matter how brilliant, followed by other lectures of the same kind, with occasionally a lucid and interesting exposition of the meaning and application of some rule, would confer an ability to read, construe or speak French? After all, it is the *student* who has to *acquire* the French. By vigorous and persistent exercise, *the student* has to possess himself of it completely. One might almost as well attempt to make a change in the plumbing of one's house by talking to it, or to drive a golf ball by the use of language—alone, as to teach French by lecturing.

It too frequently happens, although it is not a necessary part of the lecture system, that the lecture is given by one who has no

contact with the laboratory work and perhaps pays no particular attention to what is being done in the laboratory. On the other hand, the laboratory work or the discussions may be conducted by one who is not in touch with the other two parts of the instruction. That confusion and waste of effort in such circumstances should arise is not to be wondered at.

LECTURE VERSUS DISCUSSION PREPARED FOR IN ADVANCE

As I have suggested before, the successful features of language teaching might be imitated where they are applicable. For example, in Latin, we teach not merely the language but, just as continuously and unremittingly, *we teach the method of studying the language.* I find that more than half of the students in a college class have not the faintest idea how to set about studying chemistry. They spend quantities of time, yet, for lack of a method, obtain very slight results. Should we not, for example, explain to them how to notice the significance of each word in a law, and to expand the succinct terms in which it is stated? Should we not insist on their connecting each law with a set of illustrations; enjoin them to apply each illustration closely to the law, word by word; and finally advise them to close the book and see whether they can recall the facts that led up to the law, reproduce the full meaning of the terms in which it is stated, and make the application to the illustrations. Do we not simply *assume* that they will *invent* a method of study for themselves? It was years before I myself realized that I had been making this assumption, and how woefully wide of the truth it was.

It is a platitude to say that no method of teaching which disregards fundamental properties of the human mind can possibly be successful. Yet I must confess that I have used for years precisely such methods without realizing the fact. For example, the lecture places the student in a *passive and receptive attitude.* Yet it is not the reception, but the reproduction of an idea that fixes it in our memory. The *hearing* of a story makes no permanent impression. It is only after we have retold the story that it suddenly leaps into a permanent position in our repertoire. The first hearing of an idea produces but a faint track in the brain. It is the putting together of this idea, in its original setting, and also along with new ideas, that converts the first faint track into a traveled road. Is it not one of the strong points of language study, that the student must put together, in an endless variety of forms, the limited number of ideas he is trying to master, and must do this by his own efforts?

Again, *repetition,* explicit and persistent, is absolutely essential to fair acquisition. The lack of this in science teaching has recently been emphasized by President Remsen. Yet much repetition in a lecture is out of the question. It becomes tedious and boresome. It is like having the same person introduced to us formally five or six times over. We are conscious of boredom the second time, irritation the third time, rage the fourth time, and thereafter settled hatred of introducer and introduced alike whenever we hear that person's name. Yet, if we had been furnished with an opportunity spontaneously to recognize the person the second time, we should have been pleased to meet him on that occasion, we should have greeted him as an acquaintance on the third occasion, and have felt the impulse of close friendship before long. We can not alter human nature. In the study of language we have an opportunity to meet and recognize the friends whose acquaintance we first make through the dictionary, and the subsequent encounters

follow the line of our natural instincts. If we fail to recognize one of our word-acquaintances, the request for a fresh introduction comes from our *own side*. Does not the more informal discussion of chemistry in the class-room furnish just the sort of opportunity we require for continual repetition without boredom? Is the almost limitless repetition of language study one bit more than is necessary? Can we then afford to do with any less amount of it in studying a science? Can we afford to turn into lectures any of the all too few hours available for exercises in repetition and interrelation?

Finally, the student in a lecture course must *follow successfully* or he is lost. The lecturer is not a phonograph. He can not be turned back, so as to repeat the exposition of the idea which has somehow missed one of its marks, or to reproduce the key word which the student has somehow failed to catch. Extraordinary variability in the speed with which different individuals apprehend the same thing is one of the most conspicuous qualities of a group of human minds. Naturally the *lecturer* must set his speed to suit the pace of the slowest members. When the work is conducted in such a way that home preparation can not be avoided, as it easily can be, and is, for most lectures, the variable factors are eliminated from the class room and relegated to the study. Each student takes whatever amount of time is necessary for mastering the assigned lesson. And the assemblage which presents itself to the instructor is therefore of more nearly uniform quality.

If we had attempted to devise some method which should run contrary to all the conditions for successful undergraduate instruction, we could hardly have invented a scheme which would be more certain to fail than that I am discussing.

The main point is that we learn only by our own efforts, and not by watching the efforts of others. Some one has said that the college is a "gymnasium where the faculties of men are exercised and developed, rather than a boarding house where the students are crammed with facts." We develop physical muscle by *exercise*. Is there any other way of developing mental fiber? Can we ever cause mental fiber *to develop* by dealing out ready-made ideas: it is a psychologically impossible process. Is any one under the illusion that the fifteen thousand spectators at a football game get any perceptible physical exercise out of watching the performance of the teams?

The college course is to teach the student to *solve problems*. Let us beware of a method of instruction in which the facts are found, not by the student, but by the professor; in which they are arranged and related, again by the professor; in which the conclusions are drawn, by the professor; and the conclusions are finally tested, not by the student, but by the instructor. If by this process we manage to hypnotize the student into thinking that he has acquired the ability himself to solve problems, there will be a rude awakening when the time comes for him to solve problems without assistance.

A METHOD FOR TEACHING CHEMISTRY

To be more concrete, it seems to me that the following are the conditions for the teaching of college chemistry:

First, the laboratory and class-room work must run parallel with one another throughout the year, and the same subjects must be treated simultaneously in both. When separation occurs, the total "yield" is reduced to an astonishing extent, and conversely.

Second, specific laboratory exercises must

be assigned for each week. Punctual performance of these exercises must be insisted upon. The laggards must begin each week with the work of that week, before making up any leeway. Enthusiasts who would go ahead, and finally reach a point where they are performing experiments five or six weeks before they are to be discussed in the class room, must be restrained by force.

Third, the subjects for the class-room discussion must be assigned *in advance,* either from the laboratory experiments, or from the text-book, or both, and due preparation must be insisted upon in every instance. To insure preparation, a question susceptible of very brief treatment, yet dealing with some significant point, may be set at the opening of the hour. After five to ten minutes, the answers are collected, and later they are read, marked and returned. Such questions may be set at any class meeting, and as often as is necessary to secure regular preparation. The subject of the question, being now uppermost in the minds of the student, forms the best starting point for the subsequent discussion. In this way, a section containing as many as fifty to eighty students may be handled.

If the chief instructor has not time to conduct the whole of the work, *this,* the discussion or recitation, is the part of it from which his presence can least be spared. Here is the opportunity to use the maximum of knowledge, alertness and resourcefulness. Here is the place where the student shows how far he has been able to put together ideas for himself. Here is the place for repetition and interweaving. Here is the place for final removal of all difficulties and for distilling from the subject the last drop of instruction that it can yield.

During these exercises the usual demonstration experiments are shown at appropriate points.

By this arrangement the student can not feel that the laboratory work is for the acquisition of mechanical skill, or for the belated illustration of something mentioned in a past lecture. He is made to feel that it is a necessary and valuable part of the preparation for the class-room work—which is conducted so that the method of converting laboratory experience into chemical knowledge is made plain. Problems turn up unsought. The pupils have acquired at least the routine knowledge in the laboratory and at home, and the solving of the problems is almost the only thing that remains to be done in the class room. The whole time of the instructor is therefore devoted to teaching problem-solving.

I am offering these suggestions merely for what they may be worth. I have no desire to dogmatize in regard to details. I merely submit the almost self-evident proposition that the lecture-method can never play any appreciable part in training people to solve problems for themselves. Laboratory work, if dissociated from class work, will never do it either. A system which exacts continuous and thorough home-study, both of the text-book and of the results of the laboratory work, and provides for the maximum amount of the most skilfully conducted discussion of the results that can be provided, stands a strong chance of awakening and bringing to a high state of perfection this, the most essential of all the elements in the mental equipment of a human being.

If the instructor feels, for any reason, that lectures must be given, then many of the most serious defects of the system may be remedied by assigning the subjects in advance for home study, and setting a written question as described above. The whole process consumes ten minutes, but the preparation it entails makes possible the covering of nearly *twice* as much ground in the remaining forty-five minutes. Much

of the merely descriptive matter can be omitted, and the shorter explanations suffice.

SUMMARY

To return to our thesis: the college can reconstitute itself an indispensable and successful factor in American life if it will devote itself, *and confine itself*, to pre-professional work—specific work in preparation for the learned professions and for business—and if it will devote itself, *and confine itself*, to turning out men and women able to solve problems. I think we must be ready to admit that, to do these things, the college requires, and should have, a more definite source for skilled teachers, and that the college must vastly improve the methods of instruction in many of its subjects. If we as chemists can devise a method for training teachers of chemistry and can improve the methods of teaching the science themselves, we shall not only have done a service to the science, but we shall have contributed our share towards the rehabilitation of the American college. Perhaps we can do more than our share, if we are right in feeling that chemistry, appropriately taught, can furnish quite exceptional training in the art of problem-solving. We can make our contribution doubly welcome and doubly valuable if we are willing to tackle the problem at once and resolutely by scientific methods, and to put our solution quickly into practise.

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COLLEGE CHEMISTRY BEYOND THE ELEMENTARY COURSE[1]

SINCE the character of college chemistry beyond the elementary course is determined to a great extent by the nature of the introductory work, one is compelled in a discussion of this kind to make certain suppositions concerning the nature of an elementary course, and to proceed upon the basis of these assumptions.

Toward the close of the first year, by imperceptible gradations, the course in general inorganic chemistry is often allowed to flow into routine analysis. I can not help feeling that this is especially undesirable. The practise materially shortens the course in general chemistry, and takes for its own uses time which might be spent with greater profit in the study of many properties of the metals which are more varied in character than the limited number usually chosen by the analyst for the purposes of testing and identifying these same elements.

If the elementary course has given the student a somewhat thorough preparation in general inorganic chemistry—a full year with the usual number of hours of recitation, lecture and laboratory work—the college student comes to his second year with the following customary divisions of chemistry before him: Qualitative analysis, quantitative analysis, organic chemistry, physical chemistry.

It would lead me too far afield to consider all of the courses which follow the student's elementary training; so I have chosen to limit my remarks to those courses only which lie in these divisions immediately beyond the course in general chemistry.

Among these divisions, qualitative analysis in the majority of cases is the one which may most profitably be made the successor of the first year of chemistry, provided, of course, this subject is approached from the proper standpoint. I fear, however, that many of our colleges, even to-day, have not emancipated themselves from the old method of teaching this subject, but are

[1] A paper read before the Section of Education of the American Chemical Society at Detroit, July, 1909.